SALTON SEA
1995 HYDROGRAPHIC GPS SURVEY

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The Bureau of Reclamation surveyed the underwater area of Salton Sea from November 1994 through February 1995 to compile field data for developing a topographic map and computing a storage-elevation relationship (area-capacity tables). The bathymetric survey used sonic depth recording equipment interfaced with a GPS (global positioning system) that gave continuous sounding positions throughout the Salton Sea. The underwater topography was developed by a computer graphics program using the collected data. The above-water topography was determined by digitizing contour lines from the United States Geological Survey quadrangle (USGS quad) sheets that cover the Salton Sea area. The new topographic map of the Salton Sea is a combination of the digitized contours and the underwater measured topography.

As of February 1995, at Salton Sea water surface elevation 220.0 feet below sea level, the surface area was 262,517 acres with a total capacity of 9,420,566 acre-feet.

*The September 1995 version of the *Salton Sea 1995 Hydrographic GPS Survey* correctly reported 1-foot area and capacity values and equations, but revisions were required to correctly list 0.1-foot increments.

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SALTON SEA

1995 HYDROGRAPHIC GPS SURVEY

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May 1997

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Ronald Ferrari completed the underwater data processing and generated the area-capacity tables. Sharon Nuanes of the TSC completed the USGS contour digitizing. Paul Weghorst of the TSC developed the procedures for generating the new topographic maps and computing the surface areas. Jim Melena of the TSC assisted in the hydrographic collection and provided the technical peer review. Tom Hovland was the publication editor for this report.

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INTRODUCTION

The present water body of the Salton Sea, produced by an error of man, occupies parts of Imperial and Riverside Counties in California. The Salton Sea Basin (Basin), a below sea level topographic depression, extends north to Palm Springs, California, and south to the Gulf of California (fig. 1). In the geologic past, the depression was part of the Gulf of California and underwent historic cycles of filling with water and emptying because of the radical course changes of the Colorado River. The last natural filling, dated 300 to 500 years ago, to a surface elevation slightly above sea level, formed what was then called Lake Cahuilla.

For many years, the depression was a dry lake bed until irrigation water was diverted to the Imperial Valley in 1901 from the Colorado River near Yuma, Arizona. The current body of water was formed during a 16-month period during 1905 to 1907, when the Colorado River breached a temporary man-made diversion facility and discharged into the Basin. The water filled the Basin to a maximum elevation of 195.9 feet below sea level before it was diverted back into its original channel. The maximum depth of water was about 76 feet, and the water boundaries extended 45 miles in length and 25 miles in width.

Today, the Salton Sea is the largest body of water in California. It is about 35 miles long, 15 miles wide at its widest point, and has maximum depths of about 51 feet at water surface elevation 227 feet below sea level. The primary use of the Sea is to serve as a repository for storage of agricultural drainage from the Imperial Valley to the south and Coachella Valley to the north. The drainage area of the Basin is about 8,360 square miles, but the greatest inflow is produced by agricultural drainage. For many years, a near balance of inflow and evaporation effectively stabilized the Sea's water surface elevation. With the Sea no longer increasing in volume to dilute the continuous inflow of salt, its salinity increased to a current concentration of about 44,000 milligrams per liter. As the Sea has become more saline, many of the fish and wildlife, recreation, aesthetic, and economic benefits of the Sea have been reduced or threatened.

Recently, an imbalance between inflows and evaporation has caused rising water levels that have adversely affected public and private property. The flood water damage caused by the rise of the Sea, although countered by numerous constructed dikes, has resulted in multi-million-dollar law suits. The rise of the Salton Sea because of inflow increases has slightly diluted the salinity level.

The Bureau of Reclamation (Reclamation) is participating in studies with the State of California and the Salton Sea Authority, whose members include the Coachella Valley Irrigation District, the Imperial Irrigation District, Imperial County, and Riverside County. The studies include methods to manage the salinity and water surface elevation of the Sea. Many of the proposals being considered for stabilizing and reducing salinity involve construction of facilities in the Sea such as dikes and intake structures. The analysis, design, and cost estimates of these and other proposals depend upon a knowledge of the bottom elevation contours and the water capacity, thus the purpose of this study.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 1995 results of the first extensive survey of the Salton Sea. The primary objectives of the survey were to gather data needed to:

- develop underwater topography
- compute area-capacity relationships
- develop detailed topography for design analysis

The bathymetric survey was run using sonic depth recording equipment interfaced with a DGPS (differential global positioning system) capable of determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates of the survey boat as it was navigated along gridlines covering the Sea. The positioning system provided information to allow the boat operator to maintain course along these gridlines. Water surface elevations recorded by a USGS gage during the time of collection were used to convert the sonic depth measurements to true Sea bottom elevations.

The 1995 underwater surface areas at predetermined 1-foot contour intervals were generated by a computer graphics program using the collected data. The above-water areas were measured from digitized USGS quad maps of the Sea. The new topographic map of the Sea is a combination of the digitized and underwater measured topography (figs. 2 and 3). The area and capacity tables were produced by a computer program that uses measured contour surface areas and a curve-fitting technique to compute area and capacity at prescribed elevation increments.

Table 1 contains a summary of the Salton Sea's watershed characteristics for the 1995 survey. The 1995 survey determined that the Salton Sea has a storage capacity of 9,420,566 acre-feet and a surface area of 262,517 acres at water surface elevation 220.0 feet below sea level.

HYDROGRAPHIC SURVEY METHOD AND EQUIPMENT

The hydrographic survey equipment was mounted in the cabin of a 24-foot tri-hull aluminum vessel equipped with twin inboard motors. The hydrographic system contained on the survey vessel consisted of a GPS (global positioning system) receiver with a built-in radio and an omnidirectional antenna, a dual frequency depth sounder, a helmsman display for navigation, a plotter, a computer, and hydrographic system software for collecting the underwater data. Power to the equipment was supplied by an on-board generator.

The shore equipment included a second GPS receiver with a built-in radio and an omnidirectional antenna. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. A radio booster was used for this survey because of the massive area of the Sea. The power for the shore units was provided by two 12-volt batteries. Depending on conditions, the radio data link between the two GPS units ranged from 10 to 15 miles. To obtain the maximum radio transmission range, known datum points near the Sea and high above the water surface were selected.

GPS Technology and Equipment

The positioning system used at the Salton Sea was NAVSTAR (NAVigation Satellite Timing and Ranging) GPS, an all weather, radio based, satellite navigation system that enables users to accurately determine three-dimensional position. The NAVSTAR system's primary mission is to provide passive global positioning and navigation for land, air, and sea based strategic and tactical forces and is operated and maintained by the DOD (Department of Defense). The GPS receiver measures distances between satellites and itself and determines the receiver's position from intersections of the multiple range vectors. Distances are determined by accurately measuring the time a signal pulse takes to travel from the satellite to the receiver.

The NAVSTAR system consists of three segments:

- The space segment is a network of 24 satellites that are maintained in precise orbits, about 10,900 nautical miles above the earth, each completing an orbit every 12 hours.

- The ground control segment tracks the satellites, determining their precise orbits. Periodically, the ground control transmits correction and other system data to all the satellites, which is then retransmitted to the user segment.

- The user segment is the GPS receivers, which measure the broadcasts from the satellites and calculate the position of the receiver.

The GPS receivers use the satellites as reference points for triangulating their position on earth. The position is calculated from distance measurements to the satellites that are determined by how long a radio signal takes to reach the receiver from the satellite. To calculate the receiver's position on earth, the satellite distance and the satellite's position in space are needed. The satellites transmit signals to the GPS receivers for distance measurements along with the data messages about their exact orbital location and operational status. The satellites transmit two "L" band frequencies for the distance measurement signals called L1 and L2. A minimum of four satellite observations are required to mathematically solve for the four unknown receiver parameters (latitude, longitude, altitude, and time). The time unknown is caused by the clock error between the expensive satellite atomic clocks and the imperfect clocks in the GPS receivers. For hydrographic surveying the altitude, the Salton Sea water surface elevation parameter was known, which realistically meant only three satellite observations were needed to track the survey vessel. During the Salton Sea survey, a minimum of five satellites were used for position calculations, but the majority of the time, the best six available satellites were used.

The GPS receiver's absolute position is not as accurate as it appears in theory because of the function of range measurement precision and geometric position of the satellites. Precision is affected by several factors—time, because of the clock differences, and atmospheric delays caused by the effect on the radio signal by the ionosphere. GDOP (geometric dilution of precision) describes the geometrical uncertainty and is a function of the relative geometry of the satellites and the user. Generally, the closer together in angle two satellites are from the receiver, the greater the GDOP. GDOP is broken into components: PDOP is position dilution of precision (x,y,z), and HDOP is horizontal dilution of precision (x,y). The components are based only on the geometry of the satellites. The PDOP and HDOP were monitored during the Salton Sea Survey, and for the majority of the time, they were less than 3, which is well within the acceptable limits of horizontal accuracy for Class 1 and 2 level surveys.

An additional and larger error source of GPS collection is caused by false signal projection, called S/A (selective availability). The DOD implements S/A to discourage the use of the satellite system as a guidance tool by hostile forces. Positions determined by a single receiver when S/A is active can have errors of up to 100 meters.

A method to resolve or cancel GPS errors (satellite position or S/A, clock differences, atmospheric delay, etc.) is called DGPS (differential GPS). DGPS was used during this survey to determine positions of the moving survey vessel in real time. DGPS determines the relative position of one receiver to another and can increase position accuracies by eliminating or minimizing uncertainties. Differential positioning is not concerned with the absolute position of each unit but with the relative difference between the positions of the two units, which are simultaneously observing the same satellites. Inherent errors are mostly canceled because satellite transmission is essentially the same at both receivers.

At a known geographical benchmark, one GPS receiver is programmed with the known coordinates and stationed over the geographical benchmark. This receiver, known as the master or reference unit, remains over the known benchmark, monitors the movement of the satellites, and calculates its apparent geographical position by direct reception from the satellites. The inherent errors in the satellite position are determined relative to the master receiver's programmed position and the necessary corrections or differences are transmitted to the mobile GPS receiver on the survey vessel. For the Salton Sea Survey, position corrections were determined by the master receiver and transmitted via a UHF radio link every 3 seconds to the survey vessel mobile receiver. The survey vessel's GPS receiver used the corrections along with the satellite information it received to determine the vessel's differential location. Using DGPS resulted in positional accuracies of 1 to 2 meters for the moving vessel compared to positional accuracies of 100 meters with a single receiver.

The TSC (Technical Service Center) mobile and reference GPS units are identical in construction and consist of a 6-channel L1 C/A code continuous parallel tracking receiver, an internal modem, and a UHF radio transceiver. The differential corrections from the reference station to the mobile station are transmitted using the industry standard RTCM (Radio Technical Commission for Maritime Services) message protocol via the UHF radio link. The programming to the mobile or reference GPS unit is accomplished by entering necessary information via a notebook computer. The TSC's GPS system has the capability of establishing or confirming the land base control points by using notebook computers for logging data and post-processing software. The GPS collection system has the capability of collecting the data in 1927 or 1983 NAD (North American Datums) in the surveyed area's state plane coordinate system's zone, which for the Salton Sea was California Zone 6.

Survey Method and Equipment

The Salton Sea hydrographic survey collection took a total of 22 days, starting on November 4, 1994, and concluding on February 3, 1995. During this time the water surface elevations of the Sea ranged from 227.8 to 227.2 feet below sea level. The bathymetric survey was run using sonic depth recording equipment interfaced with a DGPS capable of determining sounding locations within the Sea. The survey system software was capable of recording depths and horizontal coordinates on 1-second increments as the survey boat moved along the predetermined gridlines or transects covering the Salton Sea. Because of the constant sloping underwater terrain of the Salton Sea, the data were recorded every 2 to 3 seconds; the average width between the transects was 2000 feet. The majority of the transects were run in a mostly east-west direction. Data were also collected along the shore as the boat traversed to the next transect. Transects were also run in a mostly north-south direction to provide additional data for complete contour development. The survey vessel's guidance system gave directions to the boat operator to assist in maintaining course along these predetermined gridlines. During each run, the depth and position data were recorded on the notebook computer hard drive for subsequent processing by TSC personnel. The underwater data set includes about 133,400 data points. A graph plotter was used in the field to track the boat and ensure adequate coverage during the collection process. Water surface elevations recorded by the USGS gage (near Westmorland, California) during the time of collection were used to convert the sonic depth measurements to true lake bottom elevations. Little to no wind occurred during the majority of the underwater collection, and the Sea's water surface was very calm.

The hydrographic survey crew used benchmarks as control points for shore station sites that were previously established and verified by other Federal, State, and county agencies. The hydrographic survey crew obtained additional verification by performing a static survey using the GPS receivers. Because of the size of the Sea, four master shore station locations were used for relaying correction information to the survey vessel (DGPS). Shore unit locations were Desert Shores, the Navy Base, and Travertine Rock on the west shore of the Sea and at Red Island on the south shore of the Sea. These points were selected because they had known coordinates, were accessible, were located near the Sea, and were high above the water surface. These locations allowed for good radio transmission range from the known reference survey points to the mobile survey vessel. For this survey, range varied from 10 to 15 miles between the reference and mobile GPS units. At times, the signal between the reference and mobile receivers was broken; thus, the mobile GPS receiver did not receive position corrections (DGPS). Trouble shooting determined the problem was a faulty antenna at the master GPS unit. During post processing of the collected data, all points without differential correction were removed.

The TSC's depth sounder is a dual frequency sounder with 41- and 208-kilohertz transducers available. The depth sounder determines the bottom by measuring the elapsed time between the transmission of the sound pulse from the transducer to the waterway bottom and the reception of its echo back to the transducer. The dual frequencies can be operated alone or simultaneously. The high frequency reflects off the first bottom surface and the low frequency penetrates and perhaps traces the harder sub-bottom information. After consulting with the manufacturer, it was determined that a 24-kilohertz low frequency transducer would have the best success in penetrating and tracing the harder sub-bottom. Because this information was of interest to the study team, a lease of the 24-kilohertz equipment was obtained. The collection with the 24-kilohertz equipment was conducted in areas of concern in the southern and northern portions of the Sea where soft bottom conditions were expected. Results of this collection yielded little evidence of soft bottom conditions, but no general conclusions can be made from this information because this was the first extensive use of this equipment by the TSC operator.

Periodically, the depth sounder was calibrated by lowering a deflector plate below the boat by cables with known depths marked by beads. The depth sounder was calibrated by adjusting the speed of sound, which can vary with density, salinity, temperature, turbidity, and other conditions. The accuracy of an instantaneous reading from the depth finder is estimated to be ±0.5 feet, but errors are minimized over the entire survey. The estimated accuracy takes into consideration calibration error and the collection of depth data when the boat is moving. The collected data were digitally transmitted to the computer collection system via an RS-232 port. The TSC collection system only allows one of the frequencies at a time to be stored by the computer. The high frequency data were recorded for the Salton Sea Survey. The depth sounder also produces an analog hard copy chart of the measured depths. These graphed analog charts were printed for all survey lines as the data were collected and recorded by the computer. The charts were analyzed during post processing, and when the analog charted depths indicated a difference from the recorded computer bottom depths, the computer data files were modified.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of the Salton Sea was developed from collected underwater data and from USGS 7.5 Minute Quadrangle Maps (USGS quad). The upper contours of Salton Sea were developed by digitizing the elevation -220 feet and elevation -230 feet contour lines from the seventeen USGS quad maps that cover the Salton Sea area. These USGS quad maps were dated 1956; many of them were photorevised in the 1970s. ARC/INFO V7.0.2 Geographic Information System software was used to digitize the USGS quad contours. The digitized contours were transformed to State Plane Coordinates, NAD 1927 (North American Datum of 1927), using the ARC/INFO PROJECT command.

Contours for elevations lower than -230 feet were computed from collected underwater data using the TIN (triangular irregular network) surface modeling package within ARC/INFO. The underwater survey data were collected in the California Zone 6 State Plane Coordinates in NAD 1927. The collected underwater data ranged in elevation from -278.4 feet to -230.9 feet. A TIN is a set of adjacent, non-overlapping triangles computed from irregularly spaced points with x, y coordinates and z values. TIN was designed to deal with continuous data such as elevations.

The TIN software uses a method know as Delaunay's criteria for triangulation. Triangles are formed between all data points including all boundary points. This method preserves all collected survey points. The method requires that a circle drawn through the three nodes of a triangle will contain no other point. This requirement means that sample points are connected to their nearest neighbors to form triangles. Elevation contours are then interpolated along the triangle elements. The TIN method is discussed in great detail in the ARC/INFO V7.0.2 Users Documentation.

The elevation -230-foot contour digitized from USGS quad maps was used to clip the Salton Sea TIN such that interpolation was not allowed outside of the -230-foot contour. The clip also incorporated the vertices of the -220-foot contour as additional points to be considered in the development of the Salton Sea TIN. This clip was performed using the hardclip option of the ARC/INFO CREATETIN command. In creating the TIN, points that fell within a set distance of each other were weeded out to eliminate flat triangular elements. Flat triangles occur where all three points making up a triangle have the same elevation. Elimination of redundant points helped to improve the performance of the contouring process as well as helped to create more continuous contours in the lower elevations of the reservoir.

The linear interpolation option of the ARC/INFO TINCONTOUR command was used to interpolate contours from the Salton Sea TIN. In addition, contours were generalized by weeding out vertices along the contours. This process improved the presentability of the resulting contours by removing small contour line variations. This generalization had no bearing on surface area and volume computations for the Salton Sea. The contour topography at 5-foot intervals is presented on figures 2 and 3.

Development of 1995 Contour Areas

The 1995 contour surface areas for the Salton Sea were computed in 1-foot intervals from elevation -278 to -230 using the Salton Sea TIN discussed above. These calculations were performed using the ARC/INFO VOLUME command. This command computes areas at user specified elevations directly from the TIN and takes into consideration all regions of equal elevation. This method was also used to compute the -220 contour that was digitized from the USGS quad sheets.

1995 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP85 (Reclamation, 1985). Surface areas at 1-foot contour intervals from elevation -278 to -230 and contour elevation -220, computed from the digitized and underwater survey data, were used as the control parameters for computing the Salton Sea capacity. The program can compute an area and capacity at elevation increments of 0.01 to 1.0 foot by linear interpolation between the given contour surface areas. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit, which was set at 0.000001 for the Salton Sea. This capacity equation is then used over the full range of intervals fitting within this allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from the basic area curve over that interval) tests the fit until it also exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Final area equations are derived by differentiating the capacity equations, which are of second order polynomial form:

$$y = a + a_2 x + a_3 x^2$$

where: y = capacity
x = elevation above a reference base
a = intercept
a_2 and a_3 = coefficients

Results of the 1995 Salton Sea area and capacity computations are listed in tables 1 and 2. Table 2 is a separate set of the 1995 area and capacity table at 0.1-foot elevation increments. A description of the computations and coefficients output from the ACAP85 program is included. The 1995 area-capacity curves are plotted on figure 4. As of February 1995, at elevation 220.0 feet below sea level, the surface area was 262,517 acres with a total capacity of 9,420,566 acre-feet.

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RESERVOIR SEDIMENT
DATA SUMMARY

SALTON SEA
NAME OF RESERVOIR

1
DATA SHEET NO.

D A M	1. OWNER California	2. STREAM [1]	3. STATE California
	4. SEC. 21 TWP. 11S RANGE 11E	5. NEAREST P.O. Indio, Ca	6. COUNTY Imperial/Riverside
	7. LAT 33° 11' 33" LONG 115° 49' 59"	8. TOP OF DAM [2]	9. SPILLWAY CREST [2]

RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, Ac	13. ORIGINAL CAPACITY, AF	14. GROSS STORAGE ACRE- FEET	15. DATE STORAGE BEGAN
	a. SURCHARGE					
	b. FLOOD CONTROL					1905
	c. POWER					
	d. WATER SUPPLY					16. DATE NORMAL OPERATION BEGAN
	e. IRRIGATION					
	f. CONSERVATION					
	g. INACTIVE					
	17. LENGTH OF RESERVOIR 35 MILES			AVG. WIDTH OF RESERVOIR 10 - 15 MILES		

BASIN	18. TOTAL DRAINAGE AREA 8,360 SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 2.5 INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 8,360 SQUARE MILES		23. MEAN ANNUAL RUNOFF [4] INCHES
	20. LENGTH MILES	AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF [4] ACRE-FEET
	21. MAX. ELEVATION 11,502[3]	MIN. ELEVATION -278	25. ANNUAL TEMP. MEAN 73°F RANGE 118°F to 28°F

SURVEY DATA	26. DATE OF SURVEY	27. PER.	28. ACCL.	29. TYPE OF SURVEY	30. NO. OF RANGES OR	31. SURFACE AREA, AC.	32. CAPACITY ACRE-FEET	33. C/I RATIO AF/AF
	2/95			Contour(D)	2-FT	262,517[5]	9,420,566[5]	

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIP.	35. PERIOD WATER INFLOW, ACRE FEET			WATER INFLOW TO DATE, AF	
		a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	a. MEAN ANN.	b. TOTAL

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF		
	a. TOTAL	b. AV. ANN.	c. /MI.^{2}-YR.	a. TOTAL	b. AV. ANNUAL	c. /MI.^{2}-YR.

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR.		41. STORAGE LOSS, PCT.		42. SEDIMENT	
		a. PERIOD	b. TOTAL TO	a. AV. ANNUAL	b. TOTAL TO DATE	a. PER.	b.

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, SPILLWAY CREST ELEVATION											
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR														
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-105	105-110	110-115	115-120	120-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION														
	N/A														

Table 1. - Reservoir sediment data summary (page 1 of 2).

45. RANGE IN RESERVOIR OPERATION [4]							
WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
[4]			[4]	1961	-233.8	-235.0	
1962	-233.3	-234.6		1963	-232.4	-233.9	
1964	-231.3	-232.6		1965	-232.1	-233.3	
1966	-232.1	-233.3		1967	-232.0	-233.0	
1968	-231.7	-232.7		1969	-231.7	-232.8	
1970	-231.7	-232.9		1971	-231.7	-232.8	
1972	-231.4	-232.6		1973	-231.1	-232.3	
1974	-230.8	-232.0		1975	-230.2	-231.6	
1976	-229.5	-231.1		1977	-228.6	-229.5	
1978	-228.1	-229.1		1979	-227.9	-229.4	
1980	-227.2	-228.7		1981	-227.1	-228.2	
1982	-227.4	-228.5		1983	-227.1	-228.7	
1984	-226.8	-227.7		1985	-226.9	-228.0	
1986	-226.9	-228.1		1987	-227.1	-228.3	
1988	-227.1	-228.2		1989	-227.3	-228.6	
1990	-227.7	-228.7		1991	-227.8	-228.8	
1992	-227.3	-228.7		1993	-226.9	-228.6	
1994				1995	-227.2	-227.9	

46. ELEVATION - AREA - CAPACITY DATA FOR 1995 **TOTAL CAPACITY (below sea level)**								
ELEV., FT	AREA, AC	CAP., AF	ELEV., FT	AREA, AC	CAP., AF	ELEV., FT	AREA, AC	CAP., AF
-278.6	0	0	-260.0	135,213	1,416,238	-240.0	202,308	4,768,194
-278.0	432	130	-258.0	141,845	1,693,360	-238.0	208,424	5,178,926
-276.0	13,073	12,526	-256.0	148,347	1,983,551	-236.0	214,542	5,602,108
-274.0	34,395	58,593	-254.0	154,609	2,286,530	-234.0	219,690	6,036,321
-272.0	57,079	149,950	-252.0	160,491	2,601,713	-232.0	226,249	6,482,138
-270.0	80,641	287,921	-250.0	166,302	2,928,466	-230.0	233,277	6,941,595
-268.0	98,334	468,618	-248.0	172,553	3,267,194	-228.0	239,125	7,413,997
-266.0	109,581	676,899	-246.0	179,821	3,619,490	-226.0	244,973	7,898,096
-264.0	119,237	905,824	-244.0	187,711	3,986,856	-224.0	250,821	8,393,890
-262.0	127,812	1,153,139	-242.0	195,524	4,370,319	-222.0	256,669	8,901,380
						-220.0	262,517	9,420,566

47. REMARKS AND REFERENCES

[1] Primary use is a repository for storage of agricultural drainage from Coachella and Imperial Valley. Inflow from Whitewater, Alamo, and New Rivers, and from San Felipe and Salt Creeks.

[2] Natural topographic depression filled in 1905-07 when Colorado River breached a man-made diversion structure.

[3] Summit of San Gorgonio Mountain.

[4] Multiple records available from USGS for Salton Sea water surface elevations starting in November 1904. USGS discharge data available on the creeks and rivers listed on Remark No. 1. Discharge records do not account for all drainage inflow.

[5] Surface area and capacity at elevation 220.0 feet below sea level.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE May 1995

Table 1. - Reservoir sediment data summary (page 2 of 2).

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COLORADO REGION

SALTON SEA
CALIFORNIA

TABLE 2

AREA AND CAPACITY TABLES

FEBRUARY 1995

Salton Sea tables were generated by the area-capacity program ACAP85, using the least squares method of curve fitting developed by the Bureau of Reclamation Technical Service Center. This program computes area at 1.0-, 0.1-, and 0.01-foot increments by linear interpolation between basic data contours. Respective capacities and capacity equations are then obtained by integration of area equations. The initial capacity equation is tested over successive intervals to check whether it fits within an allowable error term. At the next interval beyond, a new capacity equation (integrated from the basic area equation over that interval) begins testing the fit until it too exceeds the error term. The capacity curve thus becomes a series of curves, each fitting a certain region of data. Final area equations are obtained by differentiation of the capacity equations. Capacity equations are of the form $y = a_1 + a_2x + a_3x^2$, where y is capacity and x is the elevation above an elevation base. The capacity equation coefficients for the Salton Sea are shown below ($\epsilon = 0.000001$). *All elevations are below sea level.*

SALTON SEA — CALIFORNIA
1995 AREA-CAPACITY TABLES

Equation Number	Elevation Base	Capacity Base	Coefficient A1 (Intercept)	Coefficient A2 (1st Term)	Coefficient A3 (2nd Term)
1	-278.60	0	.0000	.0000	360.4167
2	-278.00	129	129.7500	432.5000	2605.5000
3	-277.00	3167	3167.7500	5643.5000	3714.6500
4	-276.00	12525	12525.9000	13072.8000	4630.0000
5	-275.00	30228	30228.7000	22332.8000	6031.3000
6	-274.00	58592	58592.8000	34395.4000	5612.2500
7	-273.00	98600	98600.4500	45619.9000	5729.3000
8	-272.00	149949	149949.6500	57078.5000	6016.4000
9	-271.00	213044	213044.5500	69111.3000	5764.8000
10	-270.00	287920	287920.6500	80640.9000	5284.2500
11	-269.00	373845	373845.8000	91209.4000	3562.4500
12	-268.00	468617	468617.6500	98334.3000	2994.7000
13	-267.00	569946	569946.6500	104323.7000	2628.7500
14	-266.00	676899	676899.1000	109581.2000	2467.4000
15	-265.00	788947	788947.7000	114516.0000	2360.3000
16	-264.00	905823	905824.0000	119236.6000	2276.8500
17	-263.00	1027337	1027337.4500	123790.3000	2010.9500
18	-262.00	1153138	1153138.7000	127812.2000	1887.1000
19	-261.00	1282837	1282838.0000	131586.4000	1813.2000
20	-260.00	1416237	1416237.6000	135212.8000	1690.7000
21	-259.00	1553141	1553141.0725	138593.4064	1625.5516
22	-256.00	1983550	1983550.2000	148341.6000	1581.4000
23	-255.00	2133473	2133473.2000	151504.4000	1552.4000
24	-254.00	2286529	2286530.0000	154609.2000	1513.0000
25	-253.00	2442652	2442653.3089	157628.9161	1430.8750
26	-251.00	2763635	2763635.7500	163358.7000	1471.8500
27	-250.00	2928466	2928466.3000	166302.4000	1498.7000
28	-249.00	3096267	3096267.4000	169299.8000	1626.6000
29	-248.00	3267193	3267193.8000	172553.0000	1778.4000
30	-247.00	3441525	3441525.2000	176109.8000	1855.4500
31	-246.00	3619490	3619490.4500	179820.7000	1892.4500
32	-245.00	3801203	3801206.5732	183588.7518	2061.1750
33	-243.00	4176631	4176631.7500	191850.3000	1837.0000
34	-242.00	4370319	4370319.0500	195524.3000	1717.3500
35	-241.00	4567560	4567560.7000	198959.0000	1674.4500
36	-240.00	4768194	4768194.1714	202307.7786	1529.1000
37	-238.00	5178926	5178926.1500	208424.3000	1637.1500
38	-237.00	5388987	5388987.6000	211698.6000	1421.8000
39	-236.00	5602107	5602112.0875	214519.0375	1292.7750
40	-234.00	6036325	6036325.3500	219713.3000	1562.2500
41	-233.00	6257600	6257604.5268	222817.2482	1715.7750
42	-231.00	6710105	6710105.7500	229700.9000	1788.2000
43	-230.00	6941594	6941594.8500	233277.3000	1461.9850

The Salton Sea survey in February 1995 used the contour method to obtain the basic data for these tables. Close interval profiles of the underwater portion of the Sea were collected by standard surveying techniques using a DGPS and echo sounder. The above water portion was determined from USGS topography dated 1956 and photorevised in the 1970s. Reduction of the field data was completed at the Technical Service Center in Denver, Colorado.

SALTON SEA - CALIFORNIA
1995 AREA TABLE

AREA TABLE IN ACRES — BELOW SEA LEVEL ELEVATIONS IN ONE TENTH FOOT

Note: Shaded area in right column are 1.0-foot values.

Elev. (ft)	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	.0	Elev. (ft)
-278				0	72	144	216	288	360	**432**	-278
-277	954	1475	1996	2517	3038	3559	4080	4601	5122	**5643**	-277
-276	6386	7129	7872	8615	9358	10101	10844	11587	12330	**13073**	-276
-275	13999	14925	15851	16777	17703	18629	19555	20481	21407	**22333**	-275
-274	23539	24745	25952	27158	28364	29570	30777	31983	33189	**34395**	-274
-273	35518	36640	37763	38885	40008	41130	42253	43375	44497	**45620**	-273
-272	46766	47912	49057	50203	51349	52495	53641	54787	55933	**57079**	-272
-271	58282	59485	60688	61892	63095	64298	65501	66705	67908	**69111**	-271
-270	70264	71417	72570	73723	74876	76029	77182	78335	79488	**80641**	-270
-269	81698	82755	83811	84868	85925	86982	88039	89096	90153	**91209**	-269
-268	91922	92634	93347	94059	94772	95484	96197	96909	97622	**98334**	-268
-267	98933	99532	100131	100730	101329	101928	102527	103126	103725	**104324**	-267
-266	104849	105375	105901	106427	106952	107478	108004	108530	109055	**109581**	-266
-265	110075	110568	111062	111555	112049	112542	113036	113529	114023	**114516**	-265
-264	114988	115460	115932	116404	116876	117348	117820	118292	118765	**119237**	-264
-263	119692	120147	120603	121058	121513	121969	122424	122880	123335	**123790**	-263
-262	124192	124595	124997	125399	125801	126203	126606	127008	127410	**127812**	-262
-261	128190	128567	128944	129322	129699	130077	130454	130832	131209	**131586**	-261
-260	131949	132312	132674	133037	133400	133762	134125	134488	134850	**135213**	-260
-259	135551	135889	136227	136565	136903	137242	137580	137918	138256	**138594**	-259
-258	138919	139244	139569	139894	140219	140544	140869	141194	141519	**141845**	-258
-257	142170	142495	142820	143145	143470	143795	144120	144445	144771	**145096**	-257
-256	145421	145746	146071	146396	146721	147046	147371	147696	148022	**148347**	-256
-255	148658	148974	149290	149607	149923	150239	150556	150872	151188	**151504**	-255
-254	151815	152125	152436	152746	153057	153367	153678	153988	154299	**154609**	-254
-253	154912	155214	155517	155820	156122	156425	156727	157030	157333	**157635**	-253
-252	157915	158201	158488	158774	159060	159346	159632	159918	160204	**160491**	-252
-251	160777	161063	161349	161635	161922	162208	162494	162780	163066	**163352**	-251
-250	163653	163947	164242	164536	164831	165125	165419	165714	166008	**166302**	-250
-249	166602	166902	167202	167501	167801	168101	168401	168700	169000	**169300**	-249
-248	169625	169950	170276	170601	170926	171252	171577	171902	172228	**172553**	-248
-247	172909	173264	173620	173976	174331	174687	175043	175398	175754	**176110**	-247
-246	176481	176852	177223	177594	177965	178336	178707	179079	179450	**179821**	-246
-245	180199	180578	180956	181335	181713	182092	182470	182849	183227	**183606**	-245
-244	184001	184413	184825	185238	185650	186062	186474	186887	187299	**187711**	-244
-243	188123	188536	188948	189360	189772	190185	190597	191009	191421	**191833**	-243
-242	192218	192585	192952	193320	193687	194055	194422	194790	195157	**195524**	-242
-241	195868	196211	196555	196898	197242	197585	197929	198272	198616	**198959**	-241
-240	199294	199629	199964	200299	200633	200968	201303	201638	201973	**202308**	-240

SALTON SEA - CALIFORNIA
1995 AREA TABLE

AREA TABLE IN ACRES

BELOW SEA LEVEL ELEVATIONS IN ONE TENTH FOOT

Note: Shaded area in right column are 1.0-foot values.

Elev. (ft)	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	.0	Elev. (ft)
-239	202614	202919	203225	203531	203837	204143	204449	204754	205060	**205366**	-239
-238	205672	205978	206283	206589	206895	207201	207507	207813	208118	**208424**	-238
-237	208752	209079	209407	209734	210061	210389	210716	211044	211371	**211699**	-237
-236	211983	212267	212552	212836	213120	213405	213689	213973	214258	**214542**	-236
-235	214778	215036	215295	215553	215812	216070	216329	216587	216846	**217105**	-235
-234	217363	217622	217880	218139	218397	218656	218914	219173	219432	**219690**	-234
-233	220026	220338	220651	220963	221276	221588	221900	222213	222525	**222838**	-233
-232	223160	223504	223847	224190	224533	224876	225219	225562	225906	**226249**	-232
-231	226592	226935	227278	227621	227965	228308	228651	228994	229337	**229680**	-231
-230	230059	230416	230774	231131	231489	231847	232204	232562	232920	**233277**	-230
-229	233570	233862	234154	234447	234739	235032	235324	235616	235909	**236201**	-229
-228	236494	236786	237078	237371	237663	237956	238248	238540	238833	**239125**	-228
-227	239418	239710	240002	240295	240587	240880	241172	241464	241757	**242049**	-227
-226	242342	242634	242926	243219	243511	243804	244096	244388	244681	**244973**	-226
-225	245266	245558	245850	246143	246435	246728	247020	247312	247605	**247897**	-225
-224	248190	248482	248774	249067	249359	249652	249944	250236	250529	**250821**	-224
-223	251114	251406	251698	251991	252283	252576	252868	253160	253453	**253745**	-223
-222	254037	254330	254622	254915	255207	255499	255792	256084	256377	**256669**	-222
-221	256961	257254	257546	257839	258131	258423	258716	259008	259301	**259593**	-221
-220	259885	260178	260470	260763	261055	261347	261640	261932	262225	**262517**	-220

SALTON SEA - CALIFORNIA
1995 CAPACITY TABLE

CAPACITY TABLE IN ACRE - FEET | BELOW SEA LEVEL ELEVATIONS IN ONE TENTH FOOT

Note: Shaded area in right column are 1.0-foot values.

Elev. (ft)	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	.0	Elev. (ft)
-278				0	4	14	32	58	90	**130**	-278
-277	199	320	494	720	997	1327	1709	2143	2629	**3168**	-277
-276	3769	4445	5195	6019	6918	7891	8938	10060	11256	**12526**	-276
-275	13879	15326	16864	18496	20220	22036	23946	25947	28042	**30229**	-275
-274	32522	34937	37471	40127	42903	45800	48817	51955	55214	**58593**	-274
-273	62088	65696	69417	73249	77194	81250	85420	89701	94095	**98600**	-273
-272	103220	107954	112802	117765	122843	128035	133342	138763	144299	**149950**	-272
-271	155718	161606	167615	173744	179993	186363	192853	199463	206194	**213045**	-271
-270	220013	227097	234297	241611	249041	256587	264247	272023	279914	**287921**	-270
-269	296038	304260	312589	321022	329562	338208	346959	355815	364778	**373846**	-269
-268	383002	392230	401529	410900	420341	429854	439438	449093	458820	**468618**	-268
-267	478481	488404	498387	508431	518533	528696	538919	549202	559544	**569947**	-267
-266	580405	590917	601480	612097	622766	633487	644261	655088	665967	**676899**	-266
-265	687882	698914	709996	721126	732307	743536	754815	766143	777521	**788948**	-265
-264	800423	811945	823515	835132	846796	858507	870265	882071	893924	**905824**	-264
-263	917770	929762	941800	953883	966012	978186	990405	1002670	1014981	**1027337**	-263
-262	1039737	1052176	1064656	1077175	1089735	1102336	1114976	1127657	1140378	**1153139**	-262
-261	1165939	1178777	1191652	1204566	1217517	1230505	1243532	1256596	1269698	**1282838**	-261
-260	1296015	1309228	1322477	1335763	1349084	1362443	1375837	1389268	1402734	**1416238**	-260
-259	1429776	1443348	1456954	1470593	1484267	1497974	1511715	1525490	1539299	**1553141**	-259
-258	1567017	1580925	1594865	1608839	1622844	1636882	1650953	1665056	1679192	**1693360**	-258
-257	1707561	1721794	1736060	1750358	1764689	1779052	1793448	1807876	1822337	**1836830**	-257
-256	1851356	1865914	1880505	1895128	1909784	1924473	1939194	1953947	1968733	**1983551**	-256
-255	1998400	2013282	2028195	2043140	2058116	2073124	2088164	2103236	2118339	**2133473**	-255
-254	2148639	2163836	2179064	2194323	2209613	2224935	2240287	2255670	2271085	**2286530**	-254
-253	2302006	2317512	2333049	2348616	2364213	2379840	2395498	2411186	2426904	**2442652**	-253
-252	2458431	2474236	2490071	2505934	2521825	2537746	2553695	2569672	2585678	**2601713**	-252
-251	2617776	2633868	2649989	2666138	2682316	2698523	2714758	2731021	2747314	**2763635**	-251
-250	2779986	2796366	2812776	2829215	2845683	2862181	2878708	2895265	2911851	**2928466**	-250
-249	2945112	2961787	2978492	2995227	3011993	3028787	3045612	3062467	3079352	**3096267**	-249
-248	3113214	3130192	3147204	3164248	3181324	3198433	3215574	3232748	3249955	**3267194**	-248
-247	3284467	3301776	3319120	3336500	3353915	3371366	3388852	3406374	3423932	**3441525**	-247
-246	3459155	3476821	3494525	3512266	3530044	3547859	3565711	3583601	3601527	**3619490**	-246
-245	3637491	3655530	3673607	3691722	3709874	3728064	3746292	3764558	3782862	**3801204**	-245
-244	3819586	3838007	3856469	3874972	3893516	3912102	3930729	3949397	3968106	**3986856**	-244
-243	4005648	4024481	4043355	4062271	4081227	4100225	4119264	4138345	4157466	**4176629**	-243
-242	4195836	4215075	4234352	4253666	4273016	4292403	4311827	4331288	4350785	**4370319**	-242
-241	4389889	4409493	4429131	4448804	4468511	4488252	4508028	4527838	4547682	**4567561**	-241
-240	4587473	4607419	4627399	4647412	4667459	4687539	4707652	4727800	4747980	**4768194**	-240

SALTON SEA - CALIFORNIA
1995 CAPACITY TABLE

CAPACITY TABLE IN ACRE - FEET

BELOW SEA LEVEL ELEVATIONS IN ONE TENTH FOOT

Note: Shaded area in right column are 1.0-foot values.

Elev. (ft)	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	.0	Elev. (ft)
-239	4788440	4808717	4829024	4849362	4869730	4890129	4910559	4931019	4951510	**4972031**	-239
-238	4992583	5013165	5033778	5054422	5075096	5095801	5116536	5137302	5158099	**5178926**	-238
-237	5199785	5220676	5241601	5262558	5283548	5304570	5325625	5346713	5367834	**5388988**	-237
-236	5410172	5431384	5452625	5473895	5495192	5516519	5537873	5559256	5580668	**5602108**	-236
-235	5623577	5645068	5666584	5688127	5709695	5731289	5752909	5774555	5796226	**5817924**	-235
-234	5839647	5861397	5883172	5904973	5926799	5948652	5970531	5992435	6014365	**6036321**	-234
-233	6058312	6080330	6102380	6124461	6146573	6168716	6190890	6213096	6235333	**6257601**	-233
-232	6279903	6302237	6324604	6347006	6369442	6391913	6414417	6436956	6459530	**6482138**	-232
-231	6504780	6527456	6550167	6572912	6595691	6618505	6641352	6664235	6687151	**6710102**	-231
-230	6733094	6756117	6779177	6802272	6825403	6848570	6871773	6895011	6918285	**6941595**	-230
-229	6964937	6988309	7011710	7035140	7058599	7082088	7105605	7129152	7152729	**7176334**	-229
-228	7199969	7223633	7247326	7271049	7294800	7318581	7342391	7366231	7390099	**7413997**	-228
-227	7437925	7461881	7485867	7509881	7533926	7557999	7582101	7606233	7630394	**7654585**	-227
-226	7678804	7703053	7727331	7751639	7775975	7800340	7824735	7849160	7873613	**7898096**	-226
-225	7922608	7947149	7971719	7996319	8020948	8045606	8070293	8095010	8119756	**8144531**	-225
-224	8169335	8194169	8219032	8243924	8268845	8293796	8318775	8343784	8368823	**8393890**	-224
-223	8418987	8444113	8469268	8494452	8519666	8544909	8570181	8595483	8620813	**8646173**	-223
-222	8671562	8696981	8722428	8747905	8773411	8798947	8824511	8850105	8875728	**8901380**	-222
-221	8927062	8952773	8978513	9004282	9030080	9055908	9081765	9107651	9133567	**9159511**	-221
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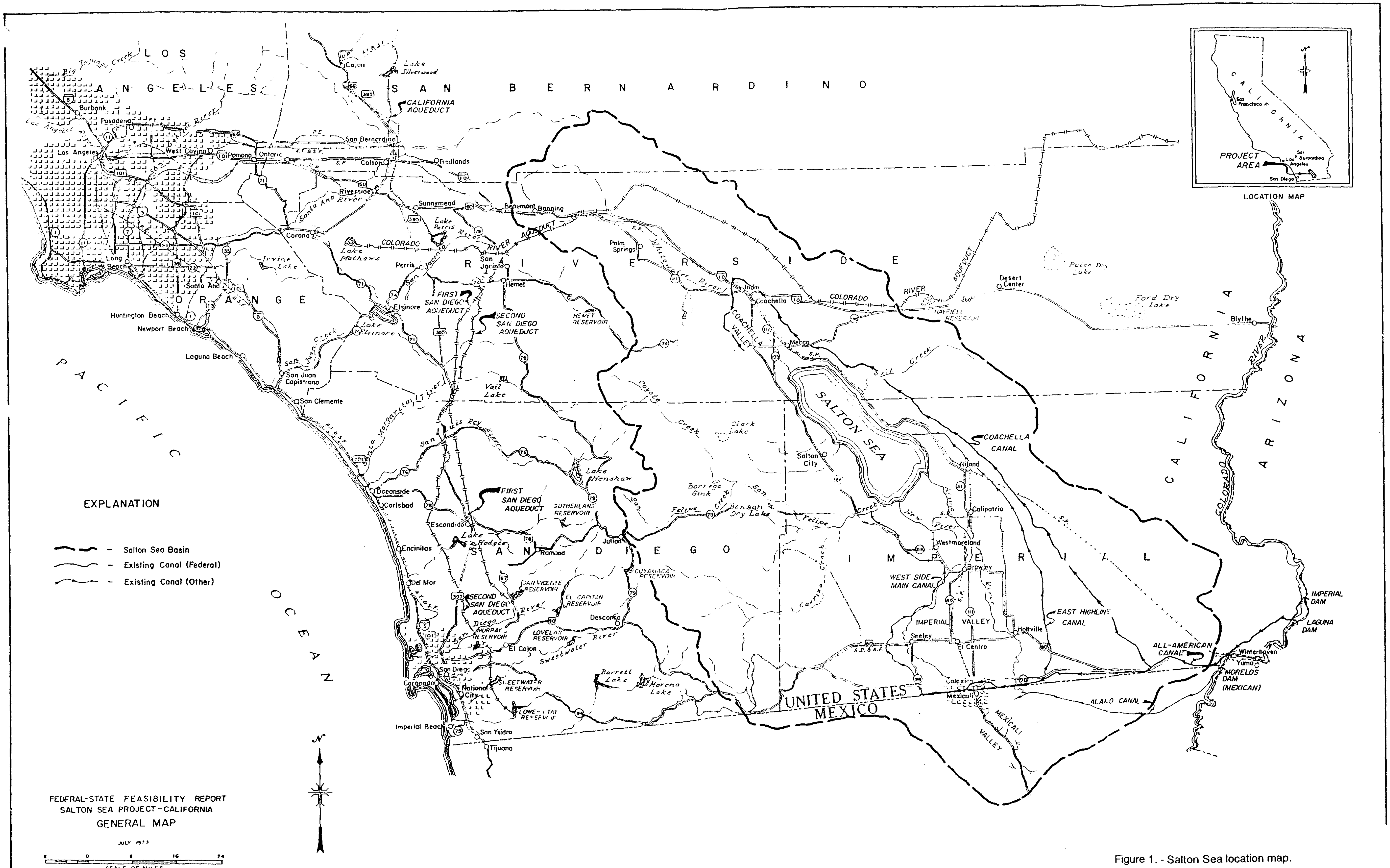

Figure 1. - Salton Sea location map.

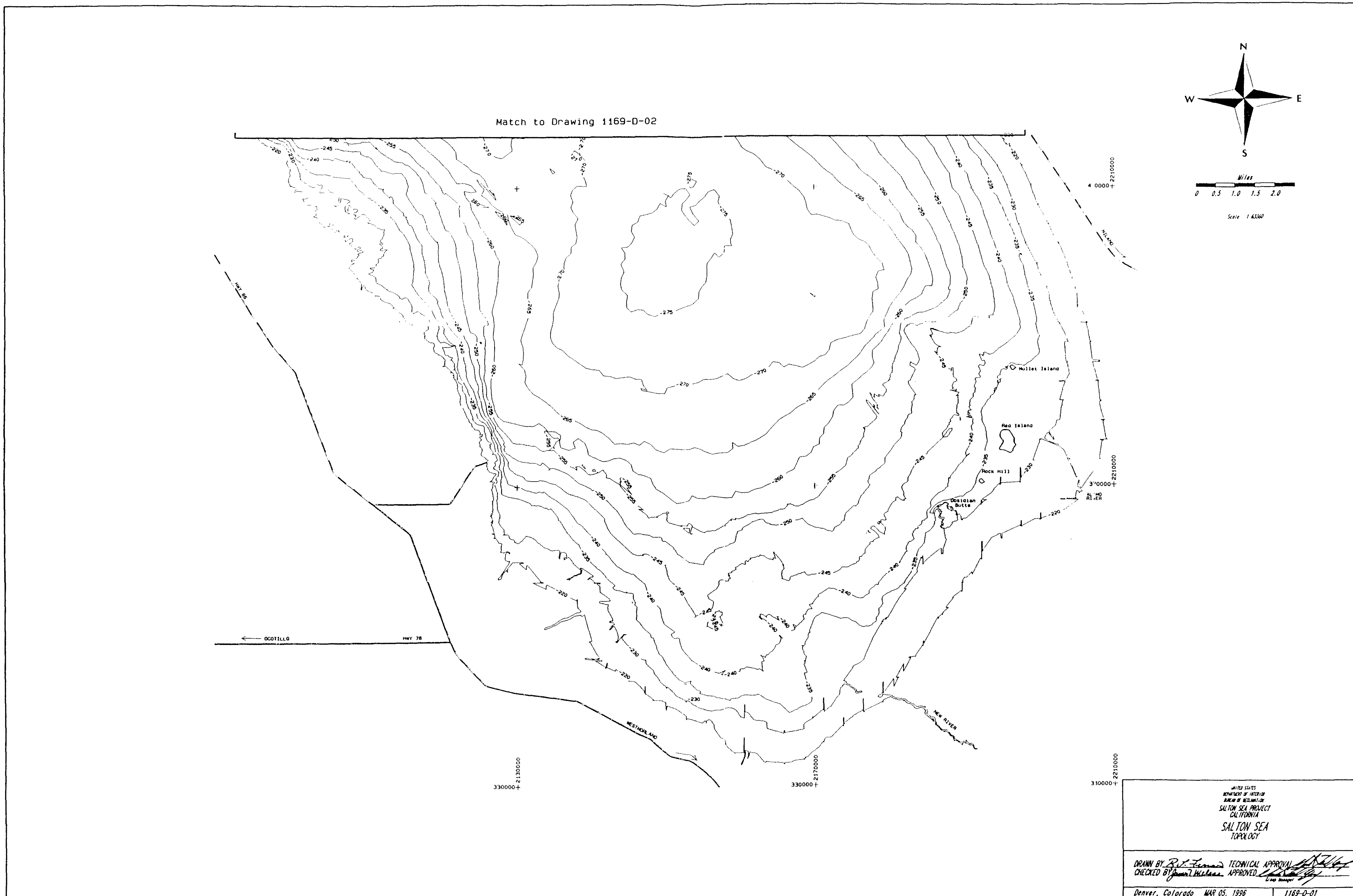

Figure 2. - Salton Sea topographic map (page 1 of 2)

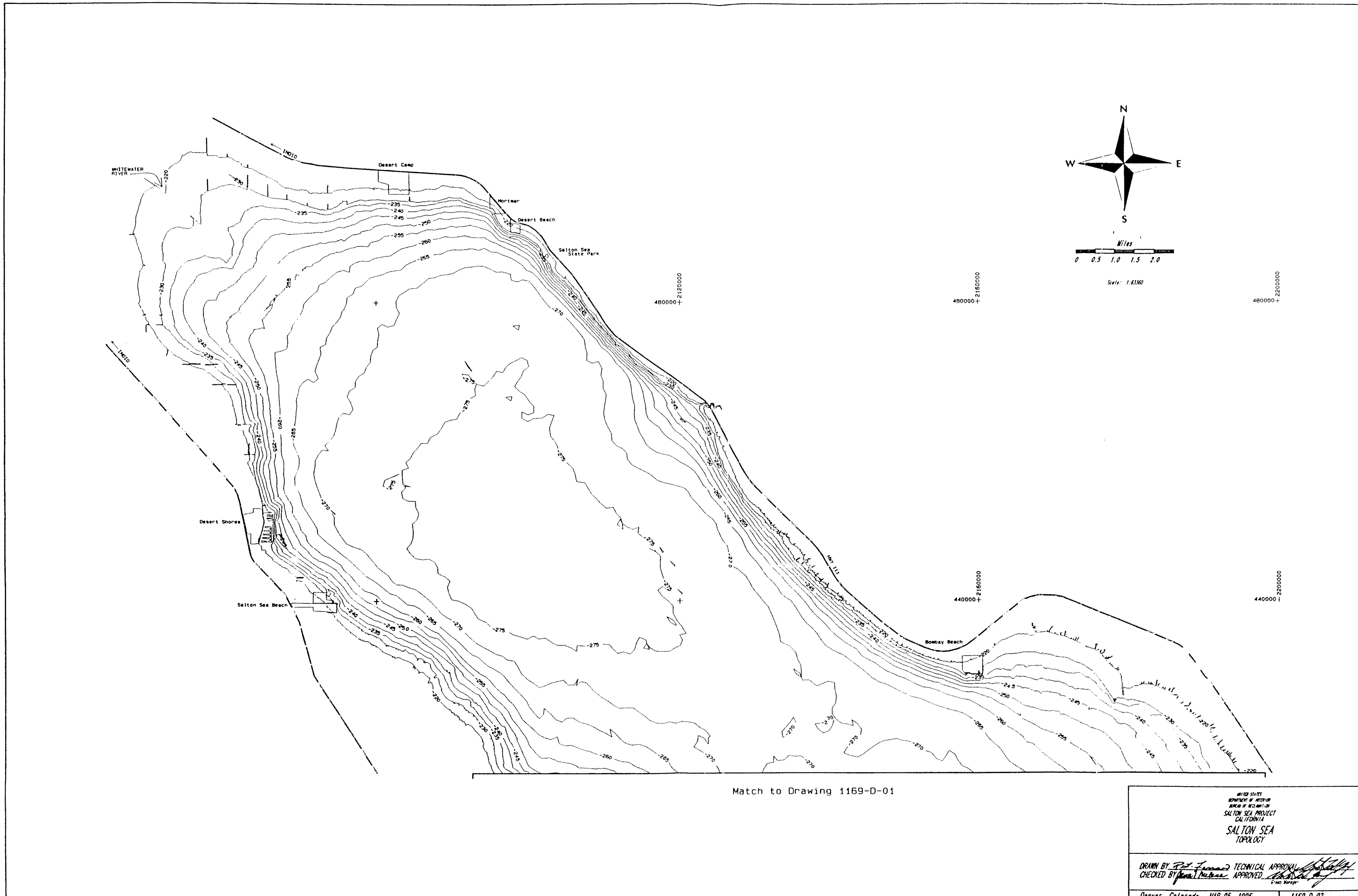

Figure 3. - Salton Sea topographic map (page 2 of 2).

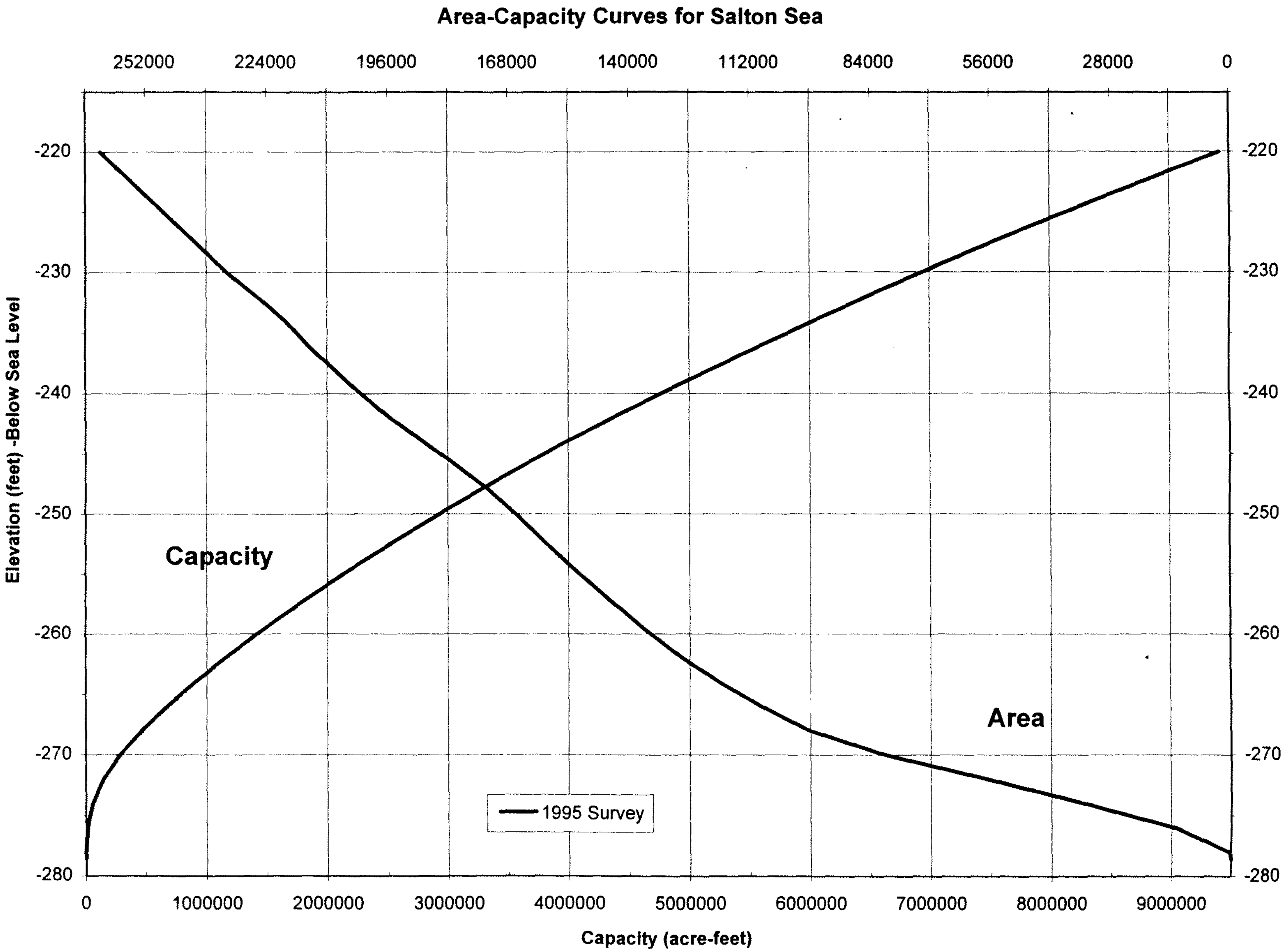

Figure 4. - Area and capacity curves—Salton Sea.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.